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Standards media and methods

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Abstract

The global marketplace and advances in information technologies are leading to great changes in standards. These include growing reliance on international standards, new standards-development techniques, and new media and environments in which standards are expressed. Both general and project-specific information are being stored in and accessed from distributed, electronic, object-oriented databases. Standards available from general-purpose information systems will be capable of accessing and processing data to evaluate compliance with their provisions. Such standards will be convenient and efficient: input data will be accessed automatically from pertinent fields of the general and project-specific databases; results of evaluations will be recorded automatically in the project-specific database and used in decisions affecting design, construction or operation of constructed facilities. Major uses of standards will be associated with computer-aided systems and major revenues from uses of standards will accrue to systems developers and users. Standards-developing organizations should respond to this marketplace by themselves producing standards in the form of executable objects. Computer aids can assist in the formulation and expression of standards that are complete in coverage of the intended scope, consistent and unambiguous in their logic, and correct in reproducing the intent of the formulators.

Keywords: Standards; Input data; Information technologies

1. Introduction

Standards and standards-developing organizations are changing markedly as the new millennium approaches. Needs for international competitiveness of products and services, environmental protection, conservation of resources, and public health and safety place increasing demands on standards. Increased reliance is placed on international standards with the globalization of commerce and the development of the World Trade Organization. Public and private organizations based on national standardization must find roles in international standardization or wither away. Simultaneously, electronic commerce is replacing traditional paper-based methods; standards must adapt to electronic media and use advanced information technologies to participate effectively in numerous computer-assisted activities. Examples from construction are computer-assisted design construction, operation, maintenance and renovation. These and other major trends are having large effects on media and methods for the formulation, expression and use of standards.

1.1. Construction standards

Construction standards are diverse in their nature and use. For instance, the definition used by the American Society of Civil Engineers is as follows.

A standard is a set of rules, conditions, or requirements concerned with: definition of terms; classification of components; delineation of procedures; speci-

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fication of dimensions, materials, performance, design or operations; description of fit and measurement of size; or measurement of quality and quantity in describing materials, products, systems, services or practices. Standards may be written in either mandatory or non-mandatory language.

Traditionally, standards have been expressed by text, including words, figures, tables and formulas, to guide the user in decision making. The user has been expected to use ancillary means, such as hand computation, to evaluate the compliance of any specific instance with the standard. In this information age, the standard can be in the form of an executable computer program that will operate on the data defining the instance to determine automatically whether the instance conforms to the standard, and if not, how the input data can be changed to achieve compliance. Such a machine representation of a standard is equivalent to a computer-based expert system, knowledge system, or intelligent agent. When the machine representation defines its own scope and interface requirements for input and output data, it becomes an 'object' for object oriented programming and databases.

1.2. Trends and issues

The General Agreement on Tariffs and Trade, administered by the recently-established World Trade Organization, discourages arbitrary national or regional variations in standards as non-tariff barriers to trade. The international treaty, multi-national corporations and advances in communications encourage the globalization of commerce and reliance on international standards for construction products and services. With the dominance of international standards, what becomes of nationally-oriented standards-developing organizations?

The global trend to highly competitive market economies is leading to downsizing of both private and public organizations that traditionally have contributed extensive 'volunteer' services to standardization. The abilities of private companies, public organizations and universities to support standards development is increasingly restricted by shortages of staff and funds. How can standards-developing organizations fund the participation of the balanced group of experts needed for high quality and consensus in standards?

Advanced information technologies, such as electronic computation, knowledge-based expert systems, electronic information systems, and the Internet for electronic communication, provide new tools for quicker formulation of higher quality standards, and new environments for the application of standards as integral parts of computer-assisted systems for design, construction, operation, maintenance and renovation of constructed facilities. Standards in electronic media will surpass paper media and methods in responding to the opportunities and challenges.

To date, most developers of computer software for design have coded what they perceive to be applicable standards into the software. This creates several problems. It is quite likely that a programmer will fail to understand the logic of the standard or fail to find all applicable provisions. Thus, it is quite likely that a program that claims to comply with one or more standards will not do so in all possible situations. Most software systems assign responsibility for correctness of results to the user, not the software developer. In addition, when standards are coded into software, it is difficult to update the software to correspond to revisions in the incorporated standards. For reliability, it is desirable that the standards-developing organizations produce the executable versions of the standards that will be incorporated into computer software. For the financial health of the standards-developing community, it also is desirable that the standards-developing organizations share in the revenues from use of standards in computer-assisted engineering.

Advanced sensors, computation and automation also are affecting the nature of constructed facilities (intelligent facilities) and construction processes (computer-integrated design, construction, operation, maintenance and renovation). The resulting changes in systems, products and processes call for new and improved standards.

The performance concept (clear and explicit relations of the provisions of standards to users' needs) is of particular importance for international standards (so that the purpose and effect of the standard will be clear to the wide variety of users) and for standards used in computer-integrated construction (because many erroneous uses could be made in a very short time).

This paper provides perspective for response of the construction standards community to these trends and issues. It does not give detailed attention to uses of advanced information technologies and media for standards. These recently have been surveyed [2] and the writer has previously provided examples of these methods [4].

2. Standards in 2001

In the near future (say 2001), standards will be an integral part of the world's general-purpose, distributed, electronically-linked information system that provides access to essentially all human knowledge. For instance, the National Standards System Network, now being developed by the American National Standards Institute, will provide a distributed electronic database with powerful search engine capability to provide access to texts of standards in electronic form. By reference or incorporation, the standards used for a specific constructed facility (whether in design, construction, operation, maintenance or renovation) should become part of the project-specific information system that support decisions throughout the whole life cycle of the constructed facility. This section provides perspective on the natures of these information systems and the standards they should incorporate.

2.1. Information systems

Evolving information systems are multi-media (text, formulas, graphs, algorithms, computer programs, pictures, speech, music, videos, etc.). Individual information systems, created and maintained by diverse organizations, will be linked by networks to provide a virtual, complete repository of the world's knowledge. Standards, as executable objects, can employ the media most helpful to their users, exist in the information systems of the standards-developing organizations, and be available for use as part of the world's information network.

Similarly, the information system specific to an individual constructed facility can include contributions from all participants in the life cycle of the project describing the results, bases and intents of their decisions. As intents (where there is an explicit performance basis) and bases for decisions, standards used can be described by reference or by actual incorporation into the project information system.

2.2. Nature of standards

A standard is self-certified by its developer to be a standard; this status may be augmented by industry, national or international recognition. A standard is a proprietary entity with intellectual property rights held by (or explicitly waived by) its developer. This proprietary nature is important for reliance by users on the quality of the standard (some entity is responsible) and for development of the funds needed to produce and maintain the standard.

The functions of standards can be augmented from those traditional for textual versions. The standard can be executed automatically for a particular instance or set of instances to assess conformity. If conformity is lacking, the reason can be noted and recommendations made for changing the data describing the instance to achieve conformance. For optimal design, when a standard does not constrain the design, it can be determined how the design can be changed with increasing optimality until the standard becomes constraining. When a standard is more general than the specific application requires, logical operations on the machine representation of the standard can create the appropriate subset for more efficient use. Similarly, when parts of a number of standards pertain, logical operations on the machine representations of the standards can create automatically a superset standard and identify whether it allows any solutions.

Performance standards address directly and explicitly users' needs such as safety, health, comfort and functionality of the product or process addressed. Since their purpose is to achieve the desired performance without constraining the nature of the solution, performance standards do not define the specific characteristics of the product or process standardized. As a result, assessment of conformance with performance standards requires high level intellectual and technical efforts: limit states (mechanisms of failure) of the specific system must be identified, models developed and empirically verified for the system's behavior, and the system shown by analysis and test to meet the performance standard.

It is practical to implement performance standards with procedural standards, each applicable to a specific type of solution and composed of provisions that assure behavior in each limit state is in conformance with the performance standard. Examples of procedural standards are those for design of buildings in the various structural materials and systems: steel, concrete, timber, masonry, etc. Procedural standards are fully consistent with the performance concept if explicit performance requirements are related to each provision. Generally, professional competence is required to evaluate conformity with procedural standards.

Prescriptive standards require specific properties and dimensions for the product or process addressed. Thus, there are few opportunities for innovation, and evaluation of conformance does not require professional skills. However, it is important to define the performance requirements addressed by the prescriptive standard and its range of validity to assure conformance with the performance requirements at hand.

Executable, electronic versions of standards appear most helpful for procedural standards; indeed, this is the area for which they first were developed [2]. For performance standards, they can support evaluation of the quantitative performance criteria, and the formulation and evaluation of the models, analyses and tests used in consideration of specific, innovative solutions. For prescriptive standards, the organizational, multi-media and database access capabilities of executable, electronic versions of standards can support the evaluation of compliance by non-professional users—e.g., helping the home owner assess the compliance of his remodeling work with the prescriptive version of the building code.

Indeed, there is no clear difference between an executable, electronic version of a standard and a well-designed user interface for software, such as a word processor, or a knowledge-based expert system. Indeed, are not these 'standards' by the definition given above? Multi-media aids can guide the user to achieving the desired solution and avoiding unwanted outcomes.

Executability facilitates the efficient and correct application of standards. Automatic access to relevant provisions of the standard, automatic defining and accessing of the input data needed for conformance assessment and carrying out the assessment, and automatic and correct filing of the results of the conformance assessment are important qualities. Principles and practices are needed for automatic linking of standards to the local database, the project information system and general-purpose information systems. (In designing in a specific steel, one would want to take time to access Internet only once to get a repeatedly referenced material property). According to a recent survey [2], substantial efforts are needed to improve techniques for automatic accessibility to provisions and data. These efforts can build on earlier work for the Standards Interface for Computer-Aided Design (SICAD) and ongoing work for automatic exchange of product data (STEP).

2.3. Examples

A number of examples can be cited to demonstrate the reality of the potential for standards as executable, computer-based objects. Considering that US regulations for federal income tax filing are a form of standard, there are several excellent computer programs available that call for the needed input data, compute one's tax obligations, warn of deductions likely to provoke an audit, and print out one's return or prepare a file for electronic submittal to the Internal Revenue Service.

Returning to the construction field, executable computer versions are available for standards such as: bridge design for the American Association of State Highway and Transportation Officials, Load and Resistance Factor Design for the American Institute for Steel Construction, Building Life Cycle Cost Analysis for ASTM, and design wind forces for the American Society of Civil Engineers.

3. Tools for developing and testing standards

This section discusses techniques for formulating and expressing standards that will exist as textual versions and as executable, multi-media, computer-based objects. The tools include performance modeling for the product or process to be standardized, use of formal logic to deal with non-numerical provisions and to control numerical computations, and expert judgement as a continuing, important basis for

standardization. Empirical tests are addressed within performance modeling since the most efficient use of testing in conformance assessment is to assure that all limit states are identified and adequately represented in performance models.

3.1. Performance modeling

Performance modeling is fundamental to the formulation and use of standards for constructed facilities since prototype testing is an inefficient method for assuring conformance of one-of-a-kind solutions. Performance models are developed, verified through analysis and testing, and made part of the world's information system. In fact, documented performance models are a type of standard—and, indeed can be executable objects.

3.2. Formal logic

Logical methods are powerful, largely unexploited tools, for formulating complete and unambiguous standards. Studies to date are cited in a recent survey [2] and logic has been used to guide the organization of standards [3]. However, much work remains to exploit the abilities of formal logic to guide the formulation of provisions, eliminate gaps and redundancies, and develop automatically a subset of a standard or a superset from a group of standards to be simultaneously applied [2].

3.3. Expert judgment

As long as human knowledge is limited, decisions must be based on judgment as well as scientifically-verified knowledge. Indeed, it is a principle of philosophy that knowledge is incomplete. Judgment-based provisions should be explicitly identified. As knowledge is gained, knowledge-based provisions can be substituted for judgment-based provisions in a standard.

3.4. Updating standards

Logic-based techniques for representation of a standard will support simple and reliable updating with automatic identification of changes in input data, information flow in assessment of compliance, and overall effects on the domain of acceptable solutions [1].

3.5. Shells for standards development

Standards are functionally the equivalent of 'expert systems' or 'knowledge systems,' including both scientific knowledge (verified data and performance models) and expert judgment. The artificial intelligence techniques used in development of expert systems are applicable to the formulation and expression of standards. The 'shell' is a general purpose program supporting the development of expert systems. Similarly, a shell or shells can be developed to support the formulation of standards as executable objects and their textual expression. A prototype shell has been described by the study of Standards Analysis, Synthesis and Expression (SASE) [1]. There is need for collaboration of standards organizations, standards participants and researchers in the development, trial use, improvement and marketing of one or more shells for standards development.

4. Issues for the standards community

4.1. Roles for prestandardization organizations

Development of recommendations for standards in the form of draft standards has been a major role for a number of international and national professional and research organizations. International examples include Euro-International Committee for Concrete (CEB), International Council for Building Research Studies and Documentation (CIB), International Union of Testing and Research Laboratories for Materials and Structures (RILEM), and International Association for Bridge and Structural Engineering (IABSE); national examples include the Structural Engineers Association of California, the American Society of Civil Engineers, and national building research organizations. This prestandardization role will become increasingly important for international standards, but may fade for national standards if they are preempted by international standards. If funding should become difficult to acquire for international prestandardization, can it attract na-

tional government or industry support, or must it depend on fees from standards' use?

4.2. Roles for national standards organizations

If national standards are supplanted by international standards, what will be the role for national standards organizations, either private or public? A number can become secretariats for selected, important international standards. All could serve to mobilize and coordinate national contributions to international standardization, and produce, where needed, complementary national standards. How would they be funded? Service as national wholesalers for international standards is unlikely to be lucrative, particularly if international standards are obtained in electronic form from Internet.

4.3. Financial support for participation in standardization

Private, academic and public organizations are downsizing to remain competitive in a world marketplace. This sharply reduces human and economic resources for participation in standardization. Economic interests and economic strength of large international corporations should continue to justify their active participation, but how will interests of the public and small- and medium-sized companies be represented?

Traditionally, standards organizations have funded their development, production and distribution activities through proceeds from sales of standards texts. However, these organizations rarely have paid the real costs of experts' efforts in prestandardization and standardization. These have been supported by voluntary contributions of efforts and government grants. As noted above, resources for voluntary activities are vanishing and national governments may feel little responsibility for international standardization.

Given that large international corporations will have incentive for 'voluntary' contributions to international standardization, three approaches are evident for obtaining participation in the public interest and that of small- and medium-sized industry: public (governmental) funds, grants from charitable foundations, and fees for standards usage.

Charitable organizations have no tradition of standards support; given the large unfilled needs of the poor, the sick and the arts, it seems unlikely that standardization will attract significant support from charitable sources.

National and regional governments have strong interests in standards effects on the welfare of their citizens and industries. They can be expected to continue and strengthen support for international standardization to the extent that they can visualize and justify benefits to their constituents. It will be a challenge to stimulate and coordinate regional and national governmental support for international standardization.

Resources of the United Nations are limited and face strong demands for maintenance of peace and for the less-developed countries. The United Nations seems unlikely to be a strong supporter or coordinator of support for standardization.

However, international electronic commerce, of which the use of standards is an integral part, offers substantial potential for funding the development and maintenance of international standards.

4.4. Income for standards organizations

Information seems to be the world's most economically important commodity. The whole information community is faced with the need to market its intellectual property through Internet. This includes data, traditionally marketed in books and reports; computer software, traditionally marketed as cards, tapes, or disks; and entertainment, traditionally marketed as books, films, videos and recordings. Producers of standards are, as are other information producers, want to be paid appropriately for each use or class of use of their property. Considering that major, sophisticated organizations, such as book publishers, movie producers and software producers must address the same problem, standards producers should observe and participate with interest in discussions and development of means to protect and be paid for intellectual property distributed through Internet. Then, standards organizations should exploit these means to obtain the funding needed to develop and maintain their standards.

For instance, most uses of constructed-related standards will be with or in computer programs for

design, construction, operation, maintenance and renovation of constructed facilities. When a mechanism is developed for payment for use of such programs, standards for the programs can be licensed to the program developers and payments for standards use made to the standards organizations by the program developers.

5. Conclusions

The global marketplace and advances in information technologies provide both needs and opportunities for changes in standards media and methods, and corresponding changes in standards-developing organizations and the funding for their work.

- International standards are of growing importance. For worldwide acceptance and use, performance bases should be explicit and clear, and the logic of standards should be transparent to users. All standards, whether performance, procedural or prescriptive, should have explicit and clear performance bases.
- Increasingly, standards are applied using electronic computation during conceptual, preliminary and detailed design and in review. Paper (text) versions are inconvenient, inefficient and unreliable.
- It is doubly undesirable to leave creation of electronic, executable versions of standards to computer programmers producing computer-assisted design systems: (1) programmers less expert in the subject matter than the standards developers are unlikely to implement the standards correctly, and (2) standards-developing organizations will lose revenue from the principal uses of the standards and lack resources needed for standards development.
- Standards should be available from databases as 'executable objects.' The term 'standard' should denote an executable, electronic version capable of computing numerically and/or logically whether the standard is met in a specific instance, if not, why, and, where possible, how the data defining the instance can be changed to achieve compliance.
- Standards organizations should produce and certify standards as electronic, executable versions of standards' texts. Soon, the textual version will be the exceptional version. Techniques developed for electronic commerce in general will provide means for users to pay for use of standards. These funds, in turn, should fully support the participation of experts in the development and maintenance of standards.
- A 'shell,' equivalent to the computer programs used to create expert systems, can be developed to support the development of electronic, executable versions and textual versions of standards. The shell will assure that the standard is 'complete' (fully covering its asserted scope), 'correct' (without ambiguity) and 'clear' (transparent to users in its scope and logic), and also will reduce the time and effort required for standards development by providing computer assistance to standards-developing teams. Systematic (and potentially competitive) efforts are needed to develop and implement shells for standards. Standards-developing organizations should support the development of the shell and recoup this investment through licensing of use of the shell for standards development.

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